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NAVORD REPORT 2932

INVESTIGATION OF MARK 18 TORPEDO FAILURES

25 AUGUST 1953

U. S. NAVAL ORDNANCE LABORATORY

WHITE OAK, MARYLAND

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SECURITY INFORMATION

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INVESTIGATION OF MARK 18 TORPEDO FAILURES

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ABSTRACT: In tests of complete Mk 18 torpedoes in Hawaii, low order action was observed in four out of fifteen trials. The torpedoes were fitted with Mk 8 Mod 7 exploder mechanisms, Mk 2 Mod 0 boosters, and Mk 8 Mod 3 detonators. Although sand tests seemed to indicate that the detonators were satisfactory, the mercury fulminate base charges of the Mk 8 Mod 3 detonators were suspected sources of the difficulty. In simulated explosive train tests, with Mk 8 Mod 3 detonators and Mk 2 Mod 0 boosters initiating three pound charges of HBX, low order action was observed in 13 of 31 trials. All trials with other types of detonators including the Mk 8 Mod 4 detonator, which has a lead azide base charge and the XE12A detonator which contains lead azide and PETN to a total of one fifteenth of the charge in the Mk 8 detonator, resulted in high order detonation of the HBX.

Mk 8 Mod 3 detonators from the same shipment gave high and reproducible sand test results. In static warhead tests at the Naval Proving Ground, Dahlgren, Virginia, charges with Mk 8 Mod 3 detonators showed low order action in two out of nine trials, while those with Mk 8 Mod 4 detonators detonated high order ten times in ten trials.

Two of the recovered warheads from the Hawaiian tests detonated high order from the action of Mk 2 Mod 0 boosters and Mk 9 Mod 4 (lead azide) detonators.

It is concluded that the mercury fulminate base charges were the most probable cause of the failures and that the sand test is an unsatisfactory criterion of detonator output.

Explosives Research Department
U. S. NAVAL ORDNANCE LABORATORY
White Oak, Maryland

NAVORD Report 2932 25 August 1953

The information presented in this report is based upon experimental work performed by the Submarine Group, Pearl Harbor; Ordnance Explosive Disposal Unit One; Naval Ammunition Deport, West Loch, Pearl Harbor; the Naval Proving Ground, Dahlgren, Virginia; and the Explosive Properties Division, Naval Ordnance Laboratory, White Oak, Maryland, and is believed to be of interest to all designers, procuring agencies, and users of ordnance in which mercury fulminate detonators are still used, as well as to those concerned with evaluation of detonator output. The investigation whose results are reported herein was authorized by task assignments Re2c-3-1-53 and C2c-3-1-54.

Important contributions to this work were made by Mr. L. D. Hampton and Mr. Theodore Bly of the Explosives Properties Division, Mr. Philipchuk and Lt. Hughes of the Naval Proving Ground, and Lt. Brookes of Ordnance Explosive Unit One. The wholehearted cooperation of all members of the organizations named above as well as Dr. W. Land, Mr. C. Lovenberg and Lt. Cmdr. Gottfried as well as others at the Bureau of Ordnance with whom the authors had contacts, did much to expedite the work.

The data and conclusion presented herein have already formed the basis for action so that the present report is intended mainly for record and information purposes.

EDWARD L. WOODYARD
Captain, USN
Commander

J. E. Ablard
J. E. ABLARD
By direction

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ILLUSTRATIONS (CON'T)

INVESTIGATION OF MARK 18 TORPEDO FAILURES

INTRODUCTION

1. It has been customary for submarines to make occasional checks of torpedo functioning by firing at cliffs. Recent failures of Mk 18 torpedoes in Hawaii caused enough concern to result in carefully controlled tests of this kind in which unexploded torpedoes were recovered. In preparation for these experiments, reference (a), the exploders, Mk 8 Mod 7, were carefully inspected and tested by specialists from Naval Underwater Ordnance Station, Newport, Rhode Island. In fifteen trials eleven torpedoes functioned satisfactorily and four functioned in a manner which was described as low order.

2. The warheads in which the low order functioning occurred are briefly described as follows: (See Figure 1)

3. Both detonators and boosters were apparently consumed except in one case where a small quantity of tetryl remained in the booster cup. The bulkhead at the back of the warhead case was blown clear and a roughly conical segment of the charge was blown out. The HBX from this segment was broken in small pieces but there was no evidence that any had exploded or burned. The exploder sustained relatively little damage.

4. Several explanations of these failures were advanced, including:

(1) Insensitive HBX - It was noted that the chunks of HBX which were recovered could be readily extinguished when burning.

(2) Partial retraction of the detonator from the booster due to the action of target impact. Examination of the unexploded warheads showed that each had struck from a quarter which could cause such retraction.

(3) Poorly loaded or deteriorated boosters - Densities of boosters were lower than is usual Navy practice.

(4) Detonator malfunctioning due to deterioration of the mercuric fulminate base charge.

(5) Detonator malfunctioning due to deterioration of the primer.

(6) Losses of explosive force due to the non-central location of the booster.

FIG. 1 RECOVERED WARHEAD WHICH HAD FUNCTIONED "LOW ORDER" IN HAWAIIAN TESTS

5. With respect to the first explanation it might be pointed out that flammability bears no direct relationship to detonability and that the ease with which it can be extinguished is a characteristic of HBX as well as other high explosives. However, the possibility still existed that the HBX in these warheads was less reactive than normal. A test described herein deals with this possibility.

6. As to the second possibility mentioned, a considerable relative motion of the exploder with respect to the warhead has been shown to be mechanically possible. No experiments are necessary to demonstrate that sufficient separation between detonator and booster can cause failure.

7. The present report deals mainly with some experiments which were designed to determine the relative probability of failure due to the third, fourth, and fifth of the proposed causes.

8. Against the fourth and fifth hypotheses, it was suggested that the apparently nearly complete consumption of the booster explosives was evidence that it had been initiated. However, tetryl can burn as well as detonate.

9. The successful use of much less centrally located boosters in other ordnance can be pointed out in answer to the sixth suggestion.

The Action of Ignited Tetryl

10. A question which was raised frequently in discussing the subject malfunctioning went:

"Suppose that the detonator explodes vigorously enough to rupture the inner wall of the booster and ignite the tetryl, but too feebly to detonate it. How would the tetryl act?"

11. A few shots were fired for the purpose of obtaining an idea regarding the answer to this question. In each of these experiments unpressed tetryl was ignited by means of a charge of black powder, a material which has never been definitely known to detonate. The tetryl was confined in a pipe nipple with caps screwed on each end, Figure 2, confined in a paint can, Figure 3, and confined in a paint can where the cover was soldered in place.

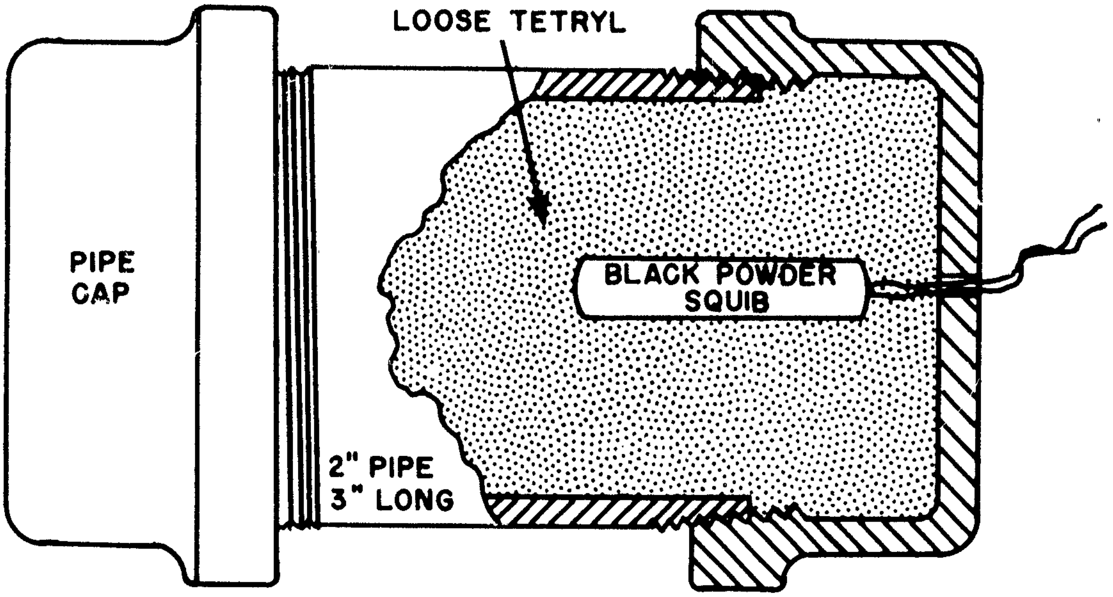

FIG. 2 LOOSE TETRYL CONFINEMENT TEST

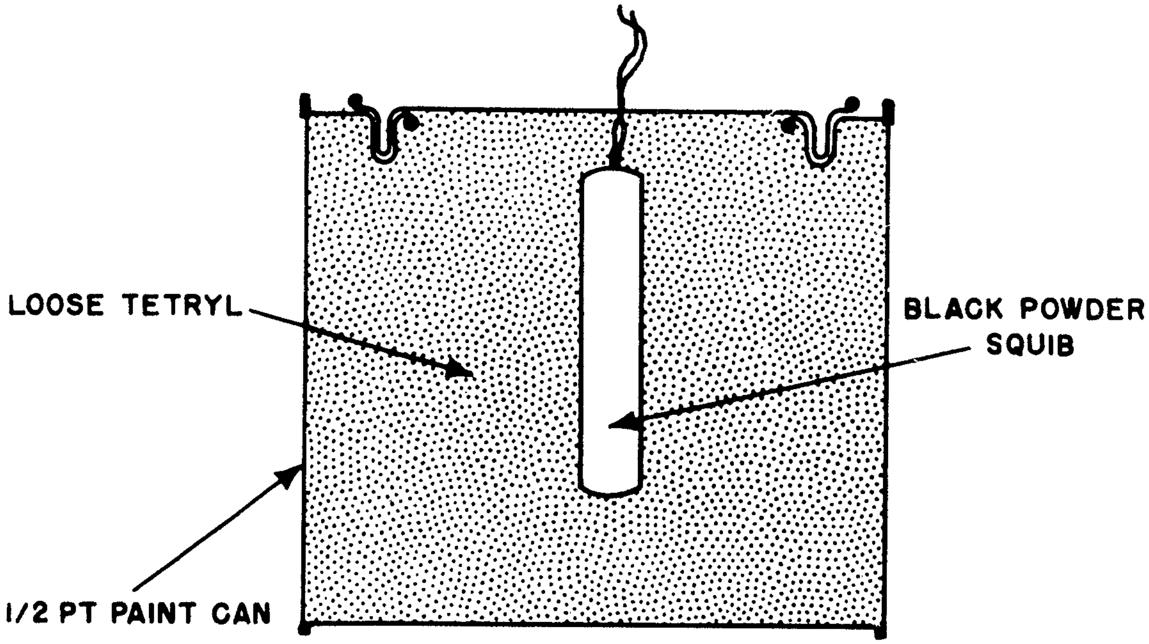

FIG. 3 LOOSE TETRYL CONFINEMENT TEST

12. When confined in the paint cans, the tetryl only reacted vigorously enough to open the can. Under the higher confinement of the pipe nipple, however, the action was much more violent than that which would result from a pressure sufficient to merely burst the pipe. The pipe was broken into fragments about the size of a quarter and the dent produced in a steel plate upon which the assembly rested was of the order of magnitude of that which the detonation of an equivalent quantity of tetryl might produce.

13. The confinement afforded the booster in the warhead is somewhere between that of the paint cans and that of the pipe nipple. The action of the tetryl in the warheads which functioned low order was also somewhere midway between that in the pipe and that in the paint can.

14. As a result of these experiments, the possibility that the malfunctioning of the warheads was due to feeble detonator action was established.

TESTS WITH SIMULATED WARHEAD EXPLOSIVE SYSTEMS

Experimental Procedure

15. As stated above, the tests at Hawaii resulted in four failures in fifteen trials. In order to obtain significant indication of any improvement in a reliability of this order of magnitude, at least eight or ten shots must be fired with each new set of conditions. Since several possible sources of failure were suggested, forty or fifty shots would probably be the minimum necessary. To fire this many full size warheads for such purposes would be extravagant of both time and money. The arrangement shown in Figures 4 and 5 was devised as a reasonable facsimile of a fully loaded warhead so far as factors affecting initiation are concerned. The distortion of the steel plate was used as a criterion of detonation, Figure 6. In all of these tests, only the detonator was varied.

16. It was at first supposed that the detonators used in the tests in Hawaii had, at some previous time, been subjected to unusual storage conditions. This supposition was founded, in part, upon the high and consistent sand test results which had been obtained by Quality Control Laboratories, reference (b), with Mk 8 Mod 3 detonators of the same lot as those used in the Hawaiian tests. For this reason the original intention was to artificially age some detonators from the same lot by

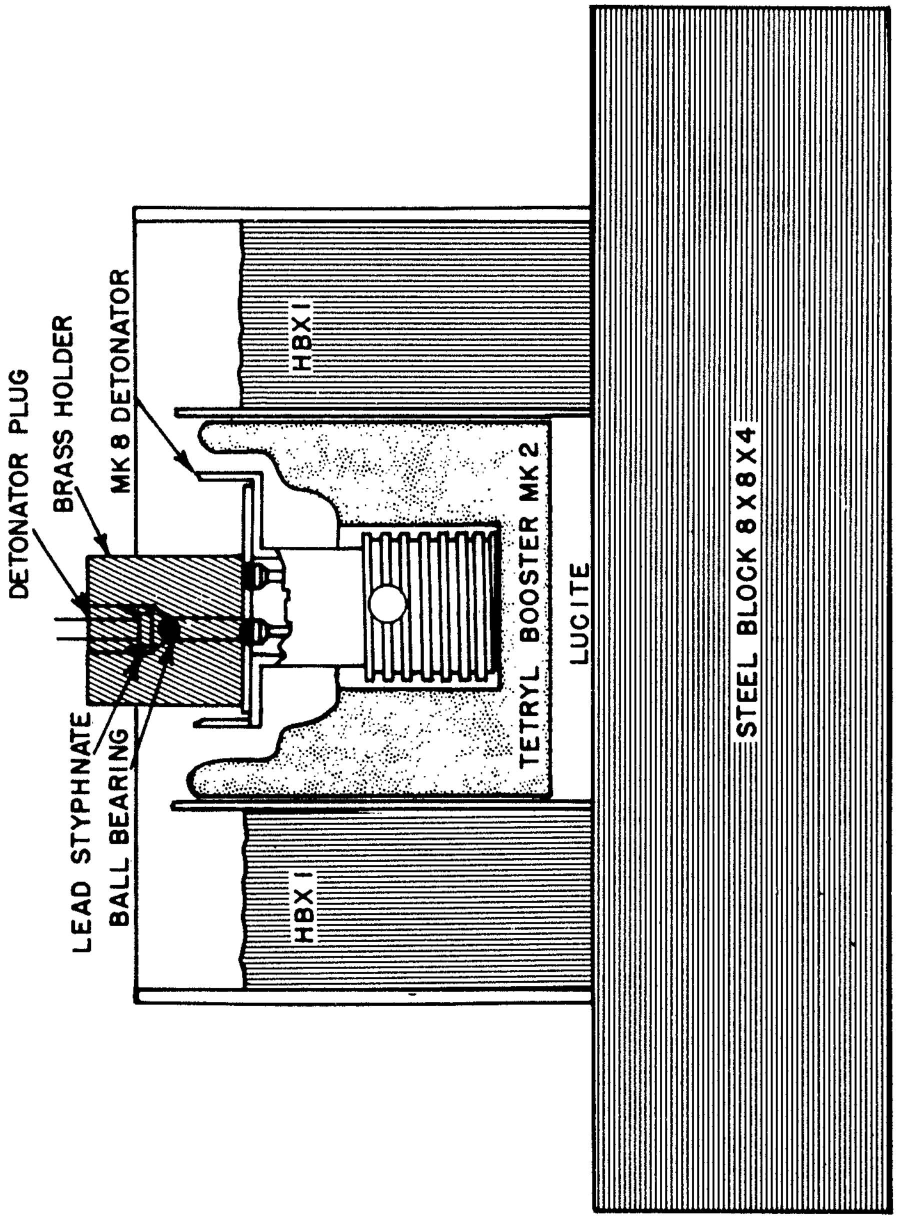

FIG.4 SIMULATED TORPEDO EXPLOSIVE TRAIN
WITH A MK 8 DETONATOR

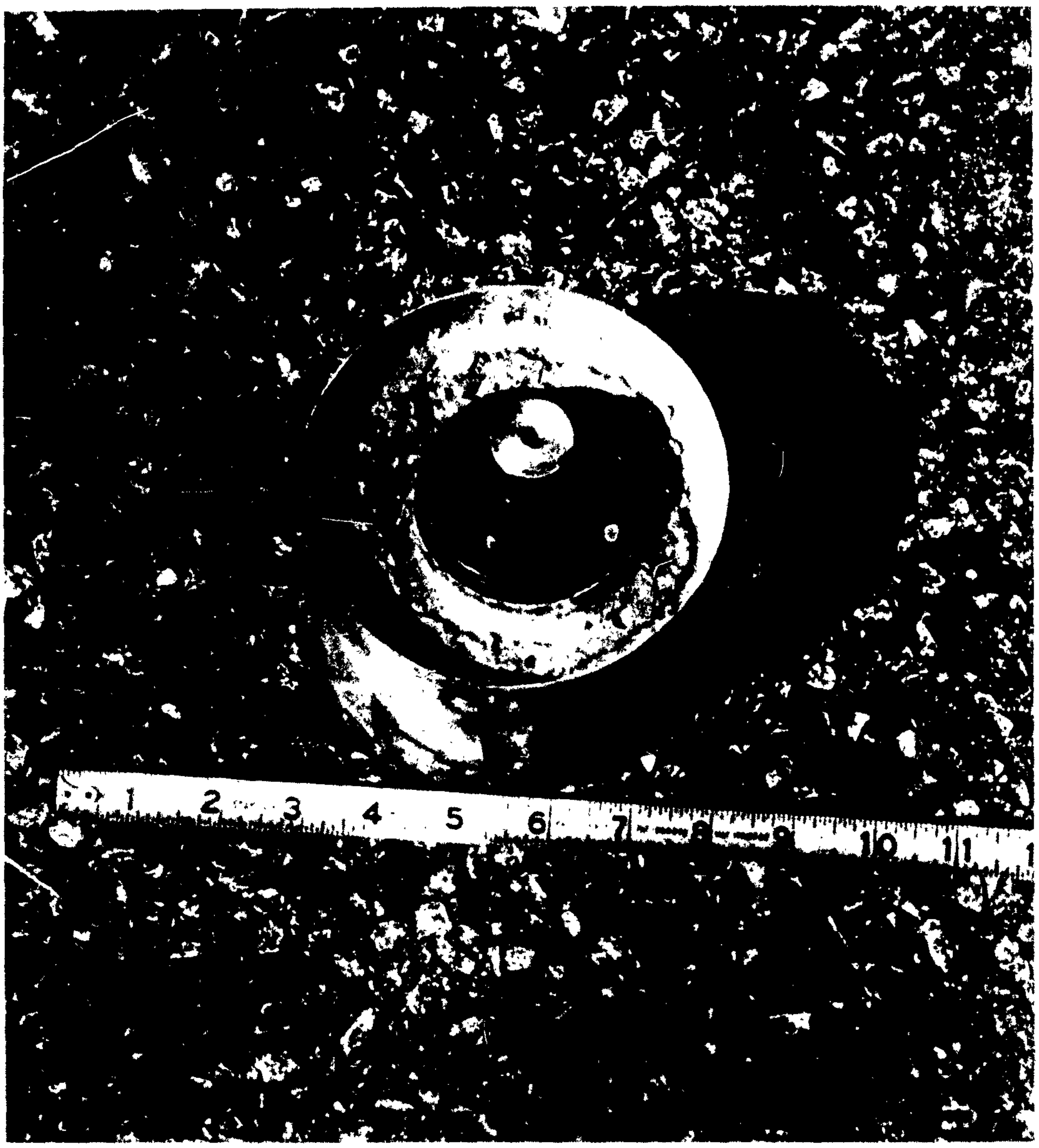

FIG. 5 SIMULATED EXPLOSIVE TRAIN WITH A MK 8 DETONATOR

FIG. 6 RESULTS OF SIMULATED EXPLOSIVE TRAIN TESTS

IN THE FOREGROUND IS A CHARGE WHICH HAS BEEN SUBJECTED TO THE LOW-ORDER ACTION OF A BOOSTER. NOTE THAT THE PLATE IS UNDAMAGED. IN THE BACKGROUND ARE SEVERAL PLATES WHICH HAVE BEEN SUBJECTED TO HIGH-ORDER ACTION OF SIMULATED EXPLOSIVE TRAINS.

heating them to 150°C, until they began to give results similar to those obtained in the Hawaiian tests. In view of the urgency of the task, this aging process was started before preparations were complete for the simulated warhead tests. Consequently, when the simulated warhead tests showed that even the detonators as received from the magazines included a substantial percentage which initiated low order, practically all of the first shipment of detonators had either been aged or fired. Another shipment was requested immediately.

17. Further experiments were run with Mk 8 Mod 3 detonators from the second shipment and with Mk 8 Mod 4 and other detonators constructed at the Naval Ordnance Laboratory, Figures 7, 8, 9, and 10.

Results and Discussions

18. Table I lists the various detonators which were used, the figure numbers, and the results obtained.

TABLE I

Detonator	Figure	Trials	High Order	Low Order
Mk 8 Mod 3				
Artificially Aged	7	8	4	4
As Received	7	14	8	6
With Mk 126 Primer	7	9	6	3
Total		31	18	13
Mk 8 Mod 4				
As Received	8	7	7	0
With Winchester #3 Primers	8	9	9	0
Total		16	16	0
Special Lead Azide	9	5	5	0
Total Lead Azide		21	21	0
Special Mercury Fulminate	9	6	6	0
XE-12A	10	8	8	0
Total		66	53	13

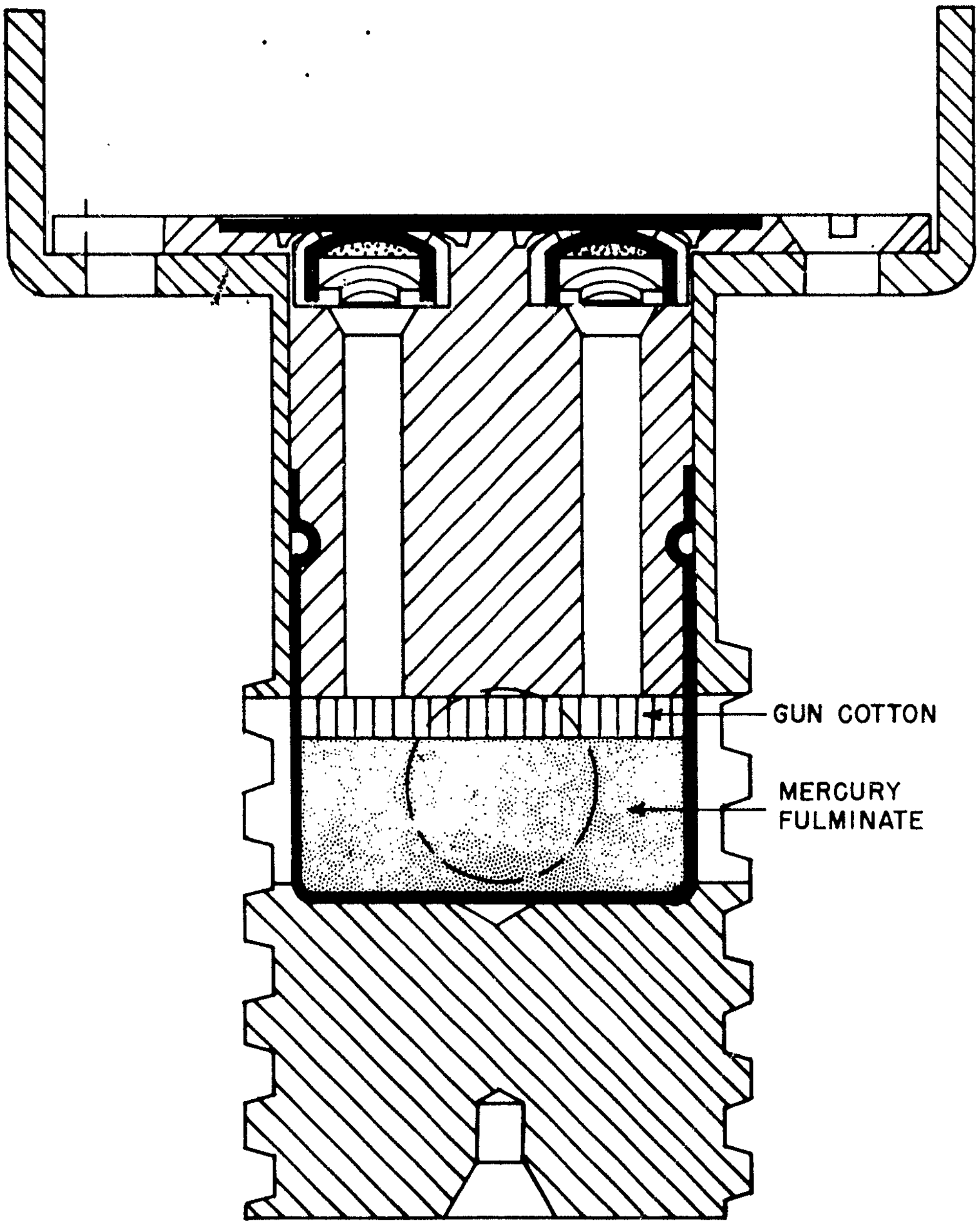

FIG. 7
DETONATOR MK 8 MOD 3

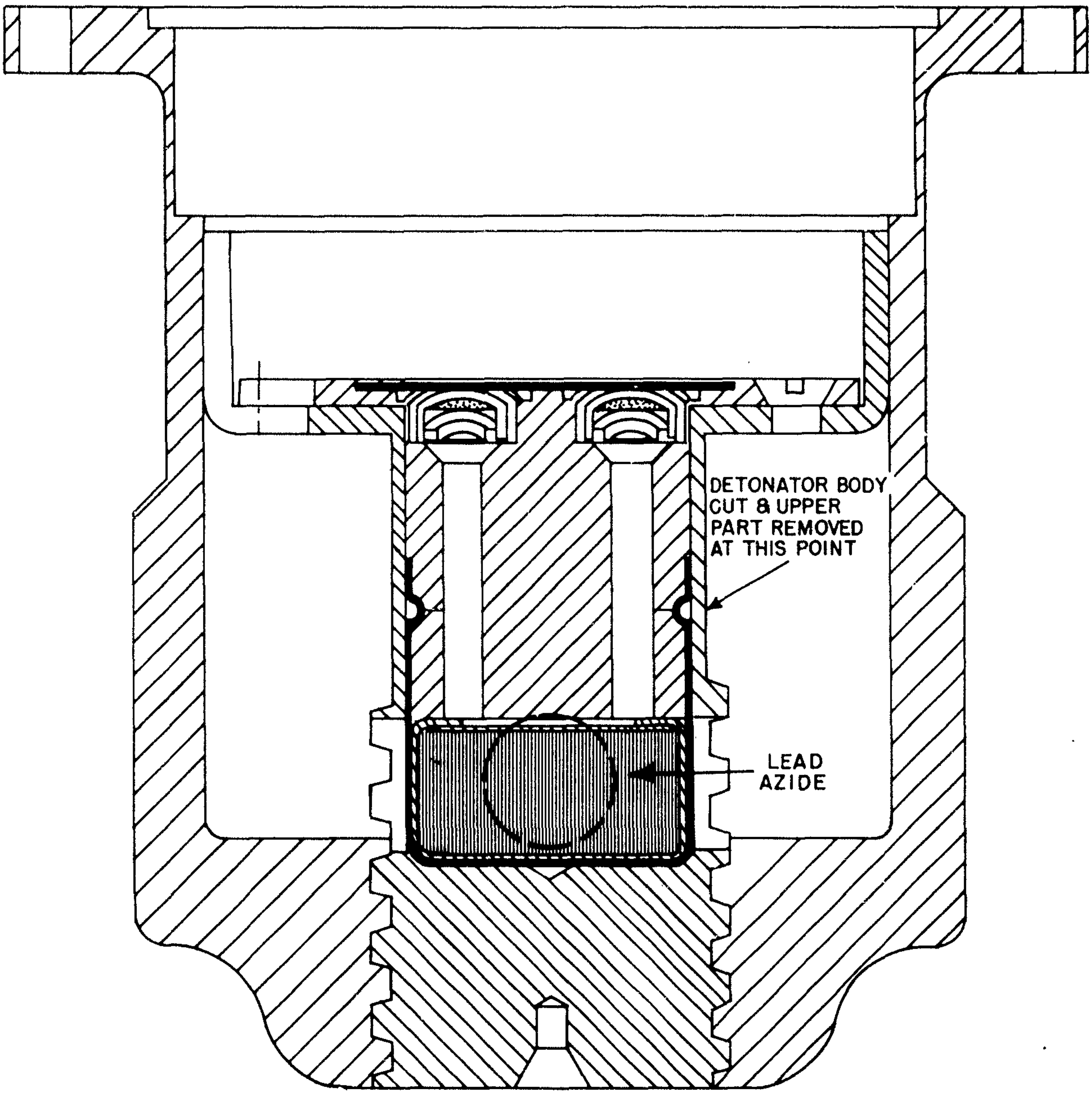

FIG. 8
DETONATOR MK 8 MOD 4

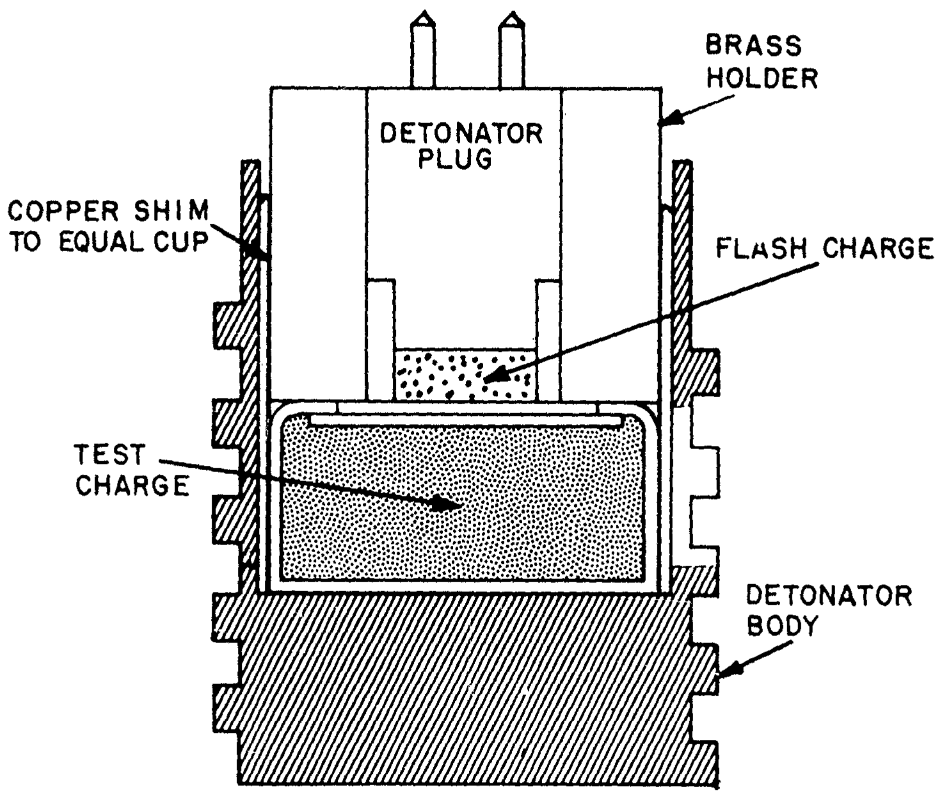

FIG. 9 TEST SETUP FOR SPECIAL DETONATOR

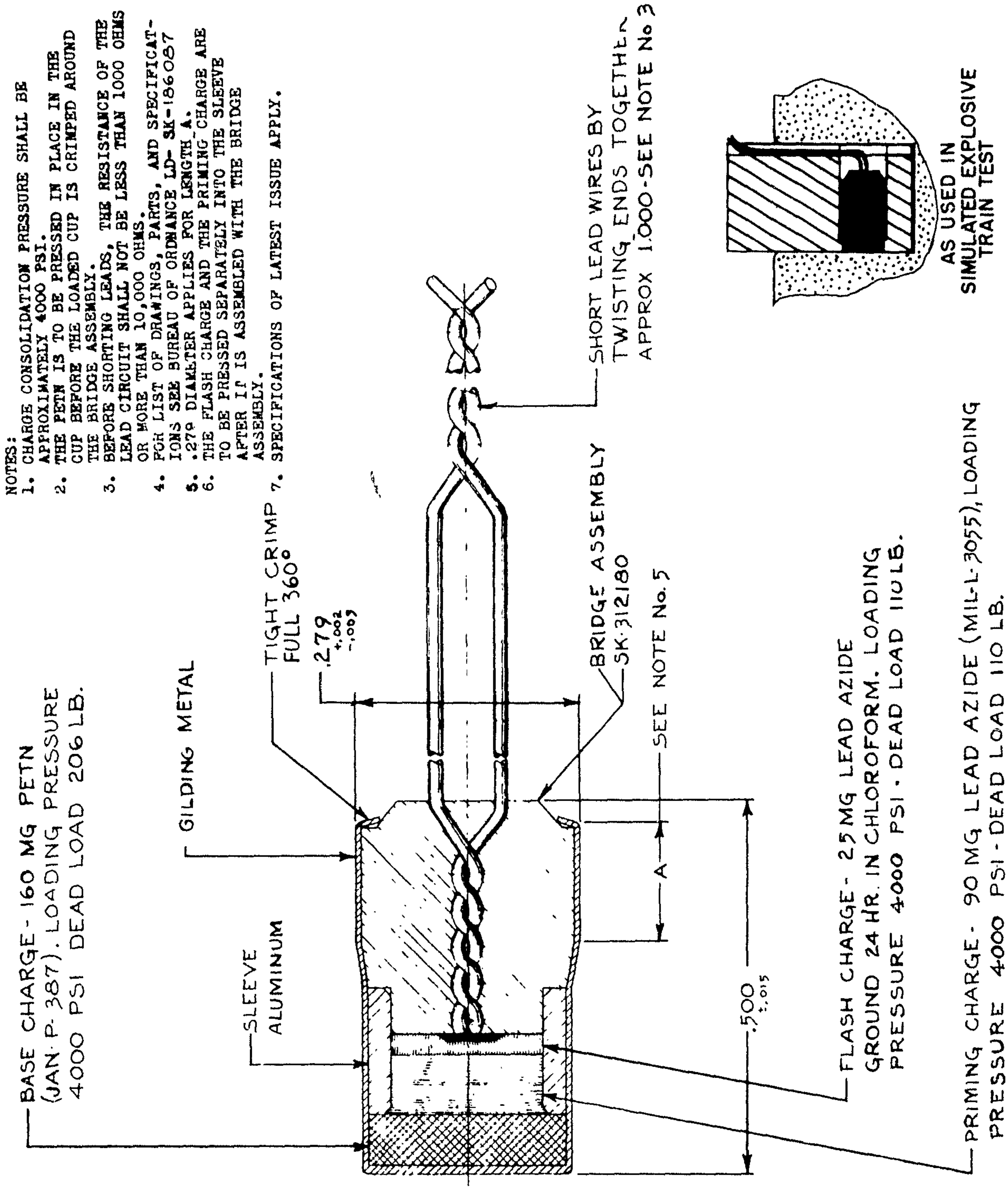

FIG. 10 DETONATOR XE-12A
(ELECTRIC)

19. It will be noted that of the total of 66 trials all 13 low order actions occurred when Mk 8 Mod 3 base charges were used. The probability of this occurring as the result of chance distribution of systems prone to failure for a reason other than detonator trouble, such as faulty boosters, for example, is only one in 20,000. The fact that 8 high order detonations occurred in 8 trials with the XE-12A detonators, Figure 10, which contain only about one fifteenth as much explosive as the Mk 8 detonators is an indication that the low orders were caused by a difference in kind of reaction of the detonator rather than merely a difference in degree.

20. It will be noted that the use of the new Mk 126 primer resulted in no significant improvement when the Mk 8 Mod 3 base charge was used and that the Mk 8 Mod 4 base charge gave nine high orders in nine trials when used with the old Winchester #3 primers. It would appear that the primers are not involved in failures of this type. This is not to say that the change in primers is unnecessary, but it is believed that primer failure would result in no action of the base charge rather than in low order action.

21. The results obtained with the mercuric fulminate when initiated by the electric initiators, Figure 9, would seem to contradict the opinion stated above. However, the electric initiators used contained 25 mg of lead azide which is ample to establish detonation in this material. It would seem that one of the first results of deterioration of mercuric fulminate is the reduction in its tendancy to make the transition from burning to detonation. It is known that very small changes in loading density can have large effects upon this tendancy. The considerable effect of a small amount of dextrin in lead azide is an indication that impurities can also have a serious effect. The inescapable conclusion of these tests is that the major source of the low order action observed in these and the Hawaiian tests is the mercuric fulminate base charge in the Mk 8 Mod 3 detonator.

22. Sand tests of Mk 8 Mod 3 and Mk 8 Mod 4 detonators were made using the Test Set Mk 151, Mod 0, Figure 11. The results are given in Table II.

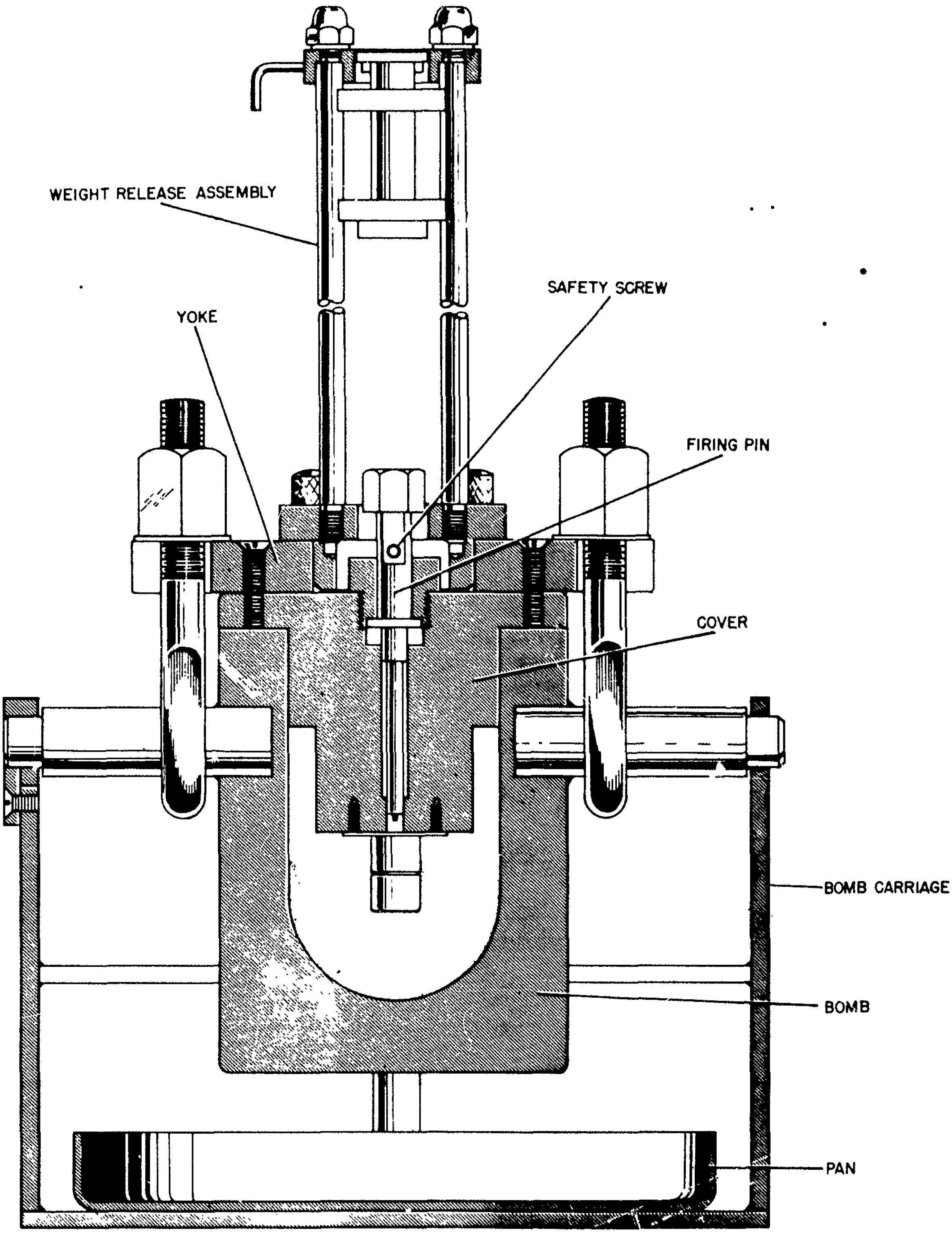

FIG. 11
TEST SET MK 151 MOD 0 (SAND BOMB)

TABLE II

RESULTS OF STANDARD SAND TEST AS PER REF (c)

Detonator	Figure	No. Trials	Sand Crushed (gms)
Mk 8 Mod 3			
Aged	7	6	184 - 208
As Received	7	2	195 - 202
Special Lead Azide	9	2	138 - 153
Special Mercury Fulminate	9	2	173 - 174

23. It will be noted that the results obtained with the Mk 8 Mod 3 detonator and the special fulminate detonator are consistently higher than those obtained with lead azide and quite reproducible.

24. One possible explanation for the good sand test results for detonators from the same group which produced low order detonation was that the sand afforded better confinement than the outer casing of the detonator which has four holes in the perifery and allows 1/16" or more clearance at the bottom in some instances. To check this possibility a series of sand tests was run with the detonators in their housings and with Scotch tape over the holes to prevent the sand from filling them and improving the confinement, Figure 12. The results of these tests are given in Table III.

TABLE III

RESULTS OF MODIFIED SAND TESTS WITH DETONATORS IN HOLDERS

Detonator	Figure	No. Trials	Sand Crushed (gms)
Mk 8 Mod 3			
As Received	6	5	191 - 205
Aged	6	15*	187 - 199
Mk 8 Mod 4	11	5	153 - 164

*The sand test data are given for the fifteen detonators out of a group of eighteen which fired. The primers of the other three failed and no explosive action was observed.

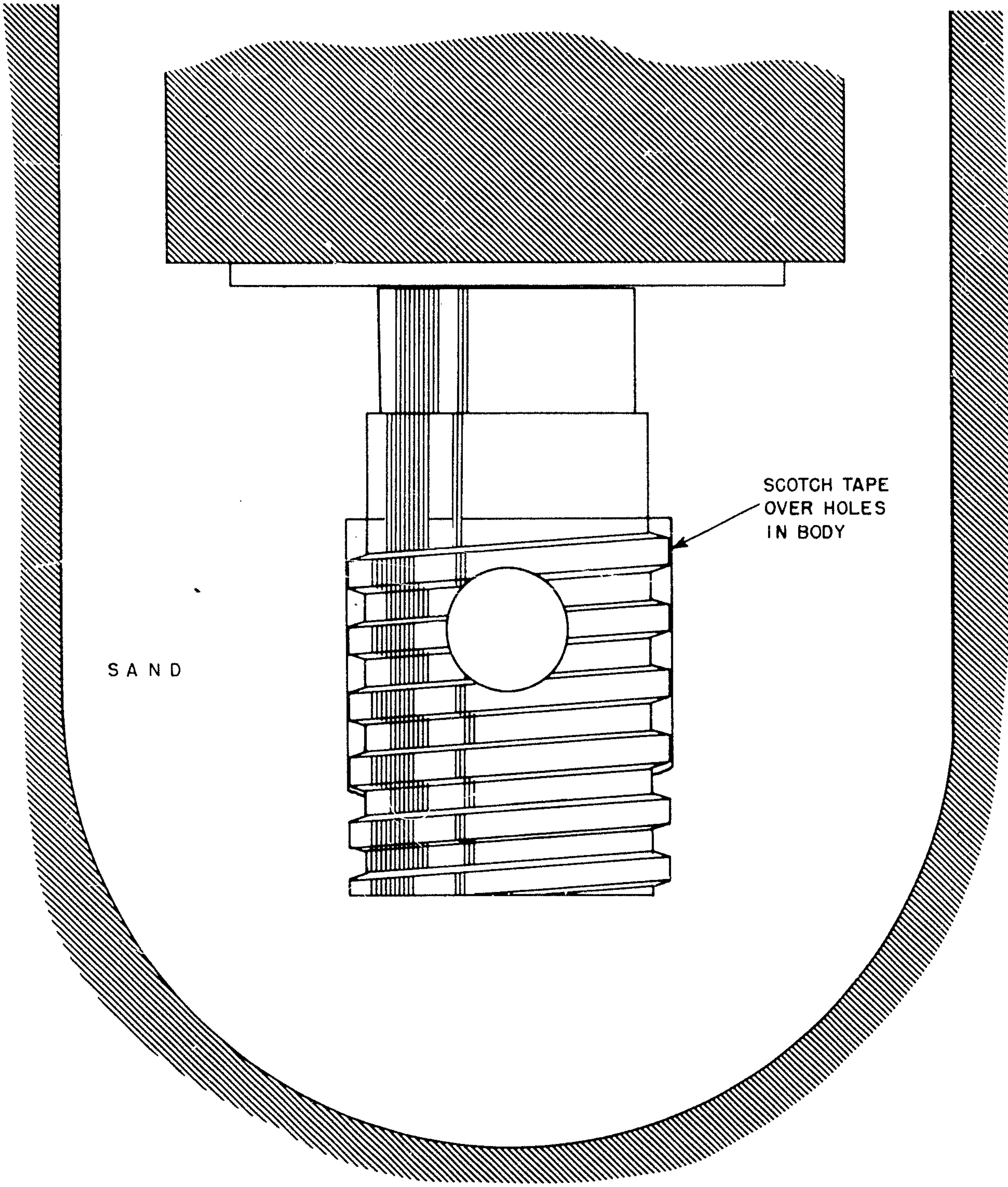

FIG. 12 MK8 DETONATOR AS USED IN SPECIAL SAND TEST

Apparently the sand test measures a property other than which is important in initiating detonation.

FULL SCALE WARHEAD TESTS

25. A group of exploders, Mk 8 Mod 7, were modified as shown in Figure 13, and in more detail in reference (d), for use by the Naval Proving Ground, Dahlgren, Virginia, in fully loaded warheads. The modifications made it possible to arm and fire the exploders by means of water conducted to the mechanism by a hose. The water was pumped by means of a fire engine through about 1,000 feet of fire hose and 50 feet of garden hose. The garden hose was used for the last 50 feet because it was considered to be more expendible. The warheads were set up as shown in Figures 14 and 15 so that in case of a failure, the exploder could be removed from a distance by pulling the rope.

26. The pressure drop in the garden hose was such that only five of the ten exploder mechanisms would operate satisfactorily. Some of the mechanisms were so stiff that it is doubted that they would work in service.

27. After adjusting and lubricating the exploders and installing the nozzles shown in dotted lines on Figure 13, four of the remaining five exploders were made to operate satisfactorily.

28. In the full scale tests at Dahlgren, reference (e), Mk 8 Mod 3 detonators as received from NMD, Yorktown, were used on nine trials. Of these, seven warheads detonated high order and two fired low order. The damage to the warheads by the low order action, Figure 16, was almost precisely the same as that reported in the Hawaiian tests, and described in the introduction to this report. Figures 17 through 22 show results of low order action from other aspects.

29. Tests of the same kind using Mk 8 Mod 4 detonators gave ten high order detonations in ten trials. See reference (f).

30. Two of the recovered warheads which had failed in the tests described in the introduction to this report were successfully detonated in Oahu, T.H. These warheads were initiated by means of Mk 2 boosters drawn from stock which were inserted in what remained of the booster wells and tamped with wet mortar. The boosters, in turn were initiated by means of Mk 9 Mod 4 detonators, the electrical analog of the Mk 8 Mod 4.

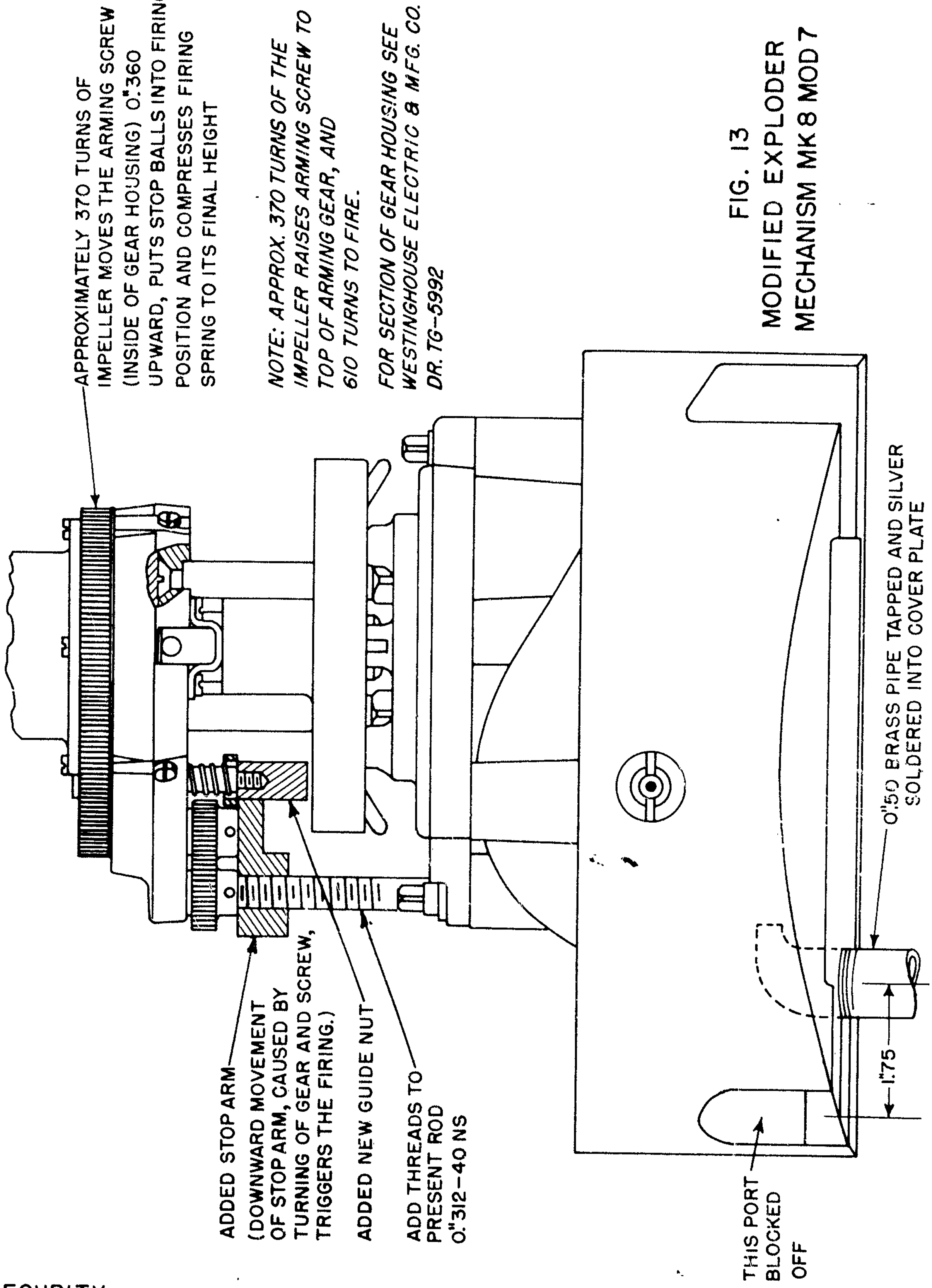

FIG. 13
MODIFIED EXPLODER MECHANISM MK 8 MOD 7

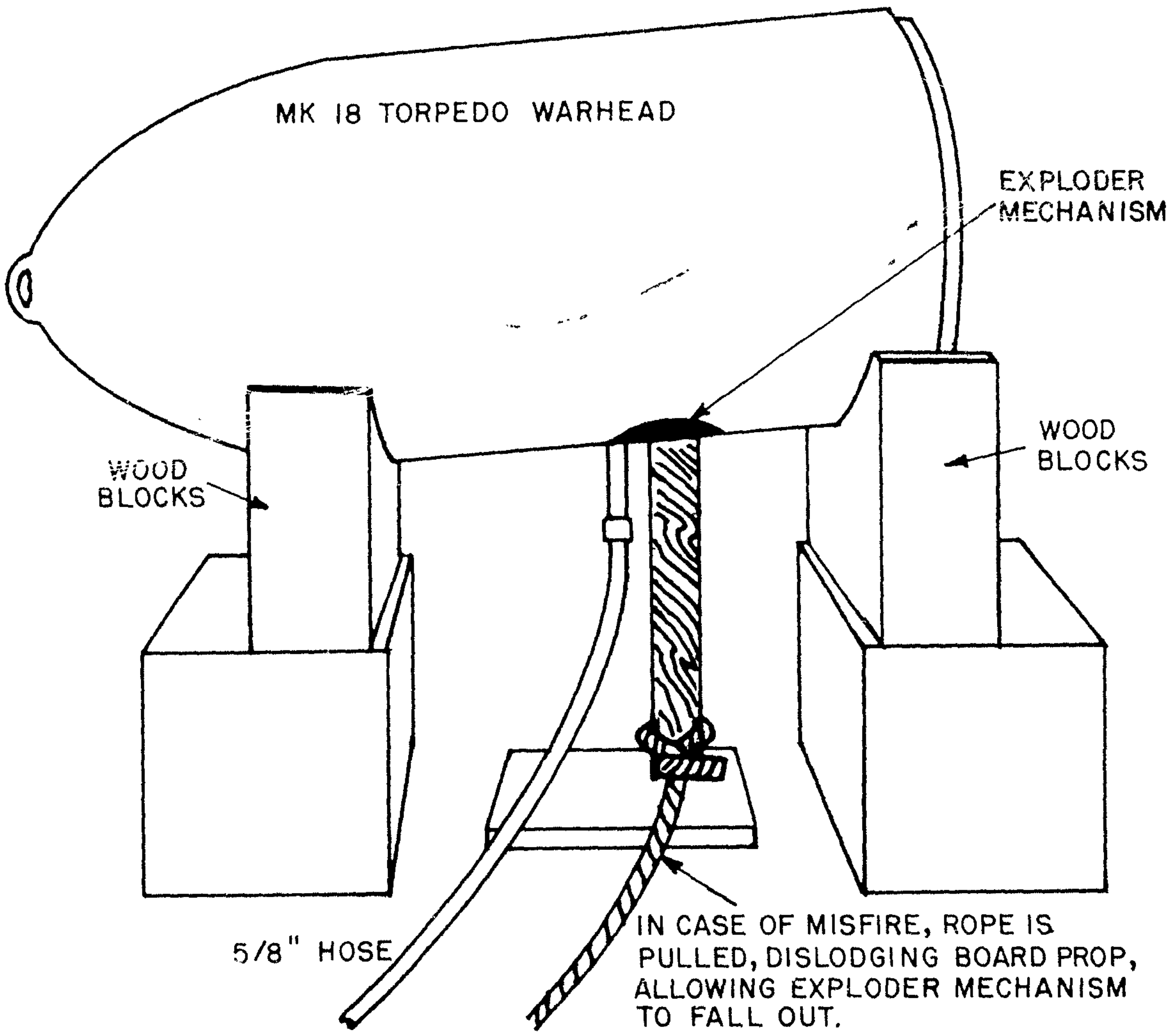
MK 18 TORPEDO WARHEAD
EXPLODER
MECHANISM
WOOD
BLOCKS
WOOD
BLOCKS
5/8" HOSE
IN CASE OF MISFIRE, ROPE IS
PULLED, DISLODGING BOARD PROP,
ALLOWING EXPLODER MECHANISM
TO FALL OUT.

FIG. 14

FIG. 16 ROUND NO. 4 OF MK 18 TORPEDO TEST. BASE END OF TORPEDO WARHEAD AFTER PARTIAL DETONATION.

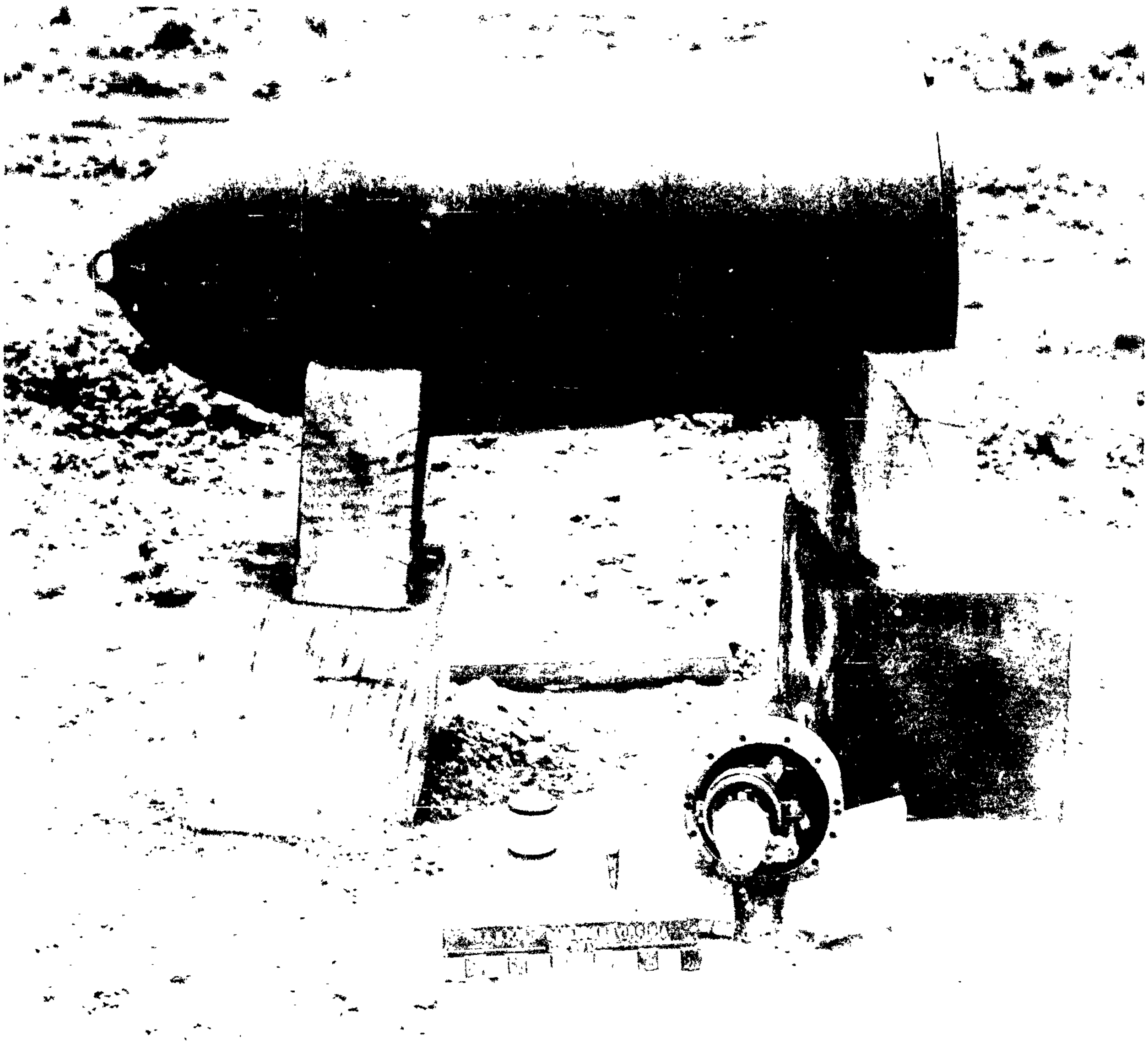

FIG. 15 TORPEDO MK 18, EXPLODER MK 8-7 ASSEMBLED WITH MK 8 MOD 3 DETONATOR, AND MK 2 BOOSTER

FIG. 17 ROUND NO. 4 OF MK 18 TORPEDO TEST AFTER PARTIAL DETONATION. NOTE EXPLODER BETWEEN WOOD BLOCKS.

FIG. 18 ROUND NO. 9 OF MK 18 TORPEDO TEST. FUZE WELL OF TORPEDO WARHEAD AFTER PARTIAL DETONATION.

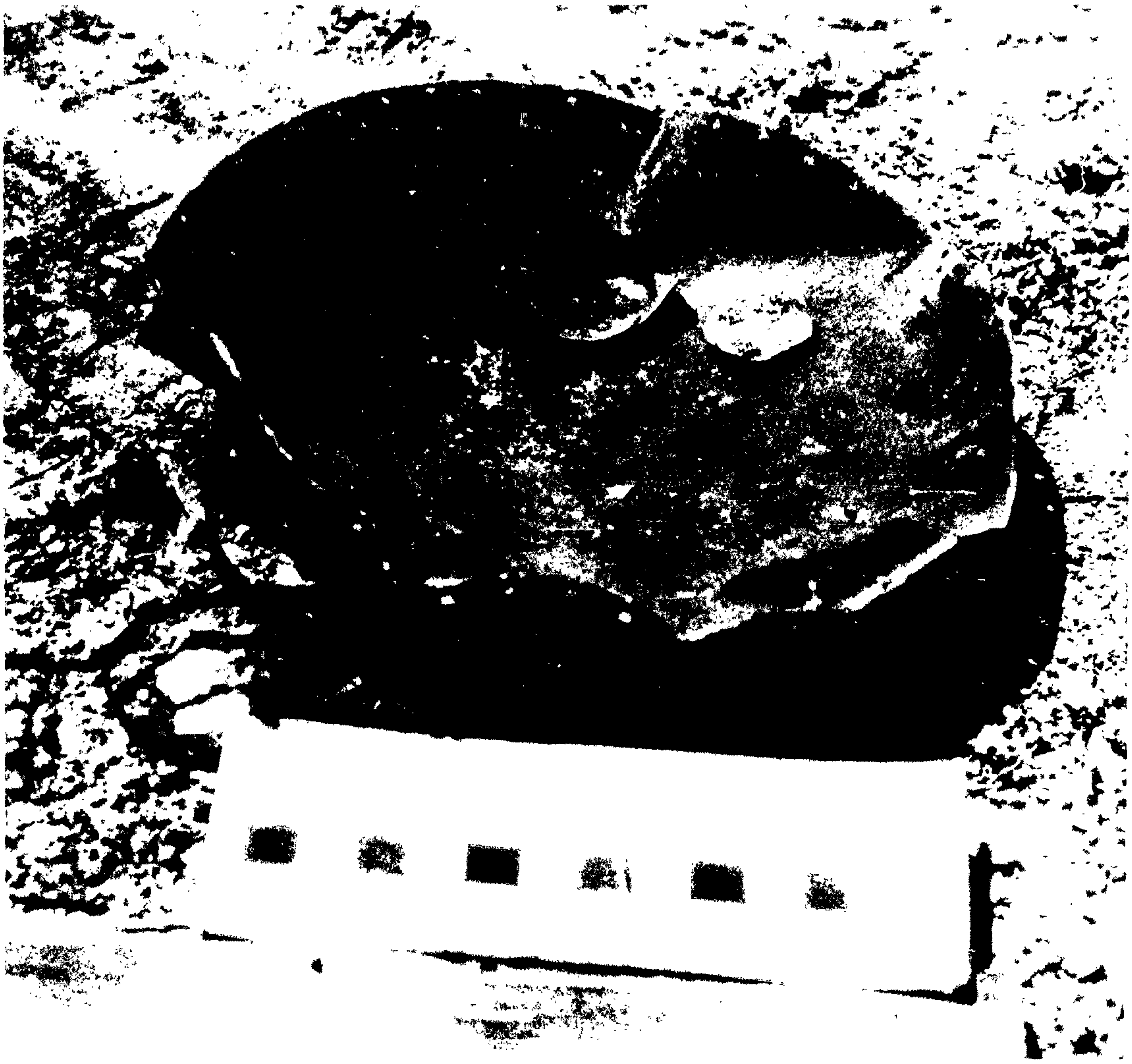

FIG. 20 ROUND NO. 4 OF MK 18 TORPEDO TEST. BASE PLATE WITH REMAINS OF MK 2 BOOSTER CAN AFTER PARTIAL DETONATION.

FIG. 21 ROUND NO. 9 OF MK 18 TORPEDO TEST. WARHEAD AND FUZE COMPONENTS AFTER PARTIAL DETONATION.

FIG. 22 ROUND NO. 9 OF MK 18 TORPEDO TEST. BASE END OF TORPEDO WARHEAD AFTER PARTIAL DETONATION.

CONCLUSIONS

31. The conclusions shown in the body of the report are that:

(1) Feeble detonator action is the probable cause of the low order actions observed.

(2) The feeble detonator action is the result of deterioration of the mercuric fulminate base charge.

(3) The sand test is useless in detecting such deterioration

RECOMMENDATIONS

32. It is recommended that:

(1) All Mk 8 Mod 3 detonators be replaced by Mk 8 Mod 4 detonators.

(2) That all other mercuric fulminate detonators be replaced.

(3) That, as suggested by others, a method be devised to fasten the booster to the exploder mechanisms. It is hardly worth while to test this in full scale tests since an excessive number of trials would be necessary to raise to a reasonable level the probability of conditions under which the device would be useful.

(4) That a jaundiced eye be cast upon sand tests as a means of detonator evaluation.

(5) That efforts to devise a more significant test of detonator output be accelerated.

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